YAG PUMPED DYE LASER FOR THE HIPAS ARCTIC LIDAR

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LONG-TERM GOAL

This is a 1997 Defense University Research Instrumentation Program (DURIP-97) award of a laser for the lidar at the UCLA HIPAS Observatory, Fairbanks, Alaska. The new 20 Hz laser will be used primarily to study the arctic sodium layer, between 90 to 130 km altitudes. It can also be tuned from 540 to 850 nm, which includes the resonant lines of barium (Ba, 553.5 nm), cesium (Ca, 852.1 nm), lithium (Li, 610.4 and 670.8 nm), potassium (K, 766.4 nm), and rubidium (Rb, 780.0 and 794.8 nm), as well as the important sodium (Na, 589.0 and 589.6 nm) lines. The new laser will emit nominally 150 mJ pulses at 590 nm, making it possible to monitor the sodium layer almost in real time with the HIPAS 2.7 meter diameter lidar collector.

SCIENTIFIC OBJECTIVES

It is now believed, by the writer, that sodium and other atoms are liberated from meteor ash by energetic solar electrons and protons that create the aurora. One irrefutable proof of this hypothesis would be the lidar detection of free lithium at 90 to 130 km during an aurora, since lithium readily combines with nitrogen to form Li_3N, and cannot exist, in either the atmosphere or ionosphere, as a free atom.

The formation of sporadic sodium layers by the electrojet will better establish the source of these metallic layers as well as lay the groundwork for their practical use, such as the generation of more intense guide stars for the correction of ground based telescopes by the technique of *Adaptive Optics*.

APPROACH

The new 20 Hz, 150 mJ/pulse (at 590 nm) laser will replace an old 10 Hz, 4 mJ/pulse excimer pumped dye laser. The original laser required 1000 laser shots or 100 seconds to record the sodium layer at 90 to 130 km with the HIPAS 2.7 m diameter Liquid Mirror Telescope (LMT) collector, on clear nights. The factor of 75 increase in average laser power means that a Na lidar record will be obtained every 1.33 seconds, almost in real time, with the new laser.

The key individuals in this project include Ralph F. Wuerker (the writer and PI) and Professor Alfred Y. Wong, Director of the HIPAS Observatory.

WORK COMPLETED

Two laser companies were identified in UCLA's DURIP 97 (September, 1996) proposal; namely, a $82,870 laser made by Spectron Laser Systems of Rugby, England (represented in the USA by Polytech PI, Inc., Auburn, MA, 01501), and a similar $135,500 laser made by Continuum Laser Systems, Santa Clara CA. The Spectron laser was ordered June 15, 1997. It will be shipped on November 14, and installed December 8-12, 1997. In the meantime, the following improvements have been completed: a two tiered optical table (which will also hold a new Alexandrite laser), a

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220 V single phase 6.5 kVA laser power supply outlet, a new higher pressure glycol-water circulating pump, and a total reflecting optical system, for directing the laser beam vertically through a Galilean telescope, to reduce the laser's beam divergence.

The new Spectron laser will be housed in the part of the lidar building that was completed last year (1996) for the Ti-sapphire laser that was replaced by an Alexandrite laser. Both lasers will be in the same room, which includes (upstairs) a screen room for the lidar's sensitive photon counting instrumentation. Figure 1 is a photograph of the completed lidar building taken March 1997. Figure 2 is a photograph of the 2.7 m aperture LMT (4.5 m focal length) which is the lidar's collector. The LMT is inside the tower (seen in Figure 1), which has a glass skylight for outside winter temperatures of -40°C.

RESULTS

As noted earlier, justification for the Doubled YAG Pumped Dye laser was based on earlier work done at HIPAS with the excimer pumped dye laser, which observed sporadic sodium layers during an auroral storm in March, 1996, as well as more recently, during the March 1997 ONR campaign, due only to the passage of the electrojet (Wuerker, et al., 1996; Wuerker, et al., 1997). Sporadic layers were independently seen by another lidar with a 0.36 m aperture collector, operated by the University of Alaska, Fairbanks, at their Poker Flats Range (Collins, et al., 1996). These observations all show that sodium is liberated from reservoirs in the ionosphere by the aurora, which itself is due to precipitating energetic solar electrons and protons caught by the earth's magnetic field and sent back to the earth's poles. Lidars in the region of Fairbanks, Alaska are uniquely situated to make these sporadic layer observations, since they pass directly under the electrojet and auroral oval on a daily basis. Lidars at lower latitudes, and even in Norway, are too far away to see the phenomena clearly.

IMPACT/APPLICATION

One important aspect of the ionospheric sodium layer is its application to the field of *Adaptive Optics*, which uses two stars to correct the effect of the atmosphere on the resolution of a ground based telescope. The two stars have to be close enough together so that rays from each pass through the same distorting cell of the atmosphere. When only one star (or target) is present, the second is created in the sodium layer by Laser Induced Fluorescence (LIF). Typical adaptive optics systems need ≥60 watts (average) of resonant laser light to create bright enough guide stars to correct a telescope with state of the art intensified systems. The notion that sodium can be released from reservoirs already in the ionosphere impacts the design of both astronomical and laser weapon adaptive optics systems. One method, recently proposed by UCLA, for releasing sodium uses a large telescope (such as the 2.7 m LMT at HIPAS) to focus a nonresonant 10 to 100 J nanosecond laser pulse to 90 km for the purpose of vaporizing meteor dust, releasing sodium, and mimicking to a certain extent what is done by the aurora (Wuerker, 1997, to be published).

TRANSITIONS

The UCLA HIPAS Observatory shares information with the University of Alaska, Fairbanks, which has a 0.36 m aperture lidar at their Poker Flat Facility (35 km north west of HIPAS). We have also shared information with the USAF Starfire Project (Albuquerque, New Mexico) and with Arecibo, Puerto Rico. Results and a description of the HIPAS lidar are presented at the RF

Interactions Workshops, held every year at the Santa Fe, New Mexico (Wuerker, et al., 1996; Wuerker, et al., 1997).

HIPAS is a part of the HAARP, HIPAS, UAF auroral research community participating in joint campaigns and sharing technical information.

RELATED PROJECTS

The HIPAS lidar was originally built to test and reduce to practice the concept of an N_2^+ lidar, as a less expensive alternative for a $30M Incoherent Scatter Radar (ISR), particularly in Alaska, where N_2^+ is one of the principal components of the aurora (Wuerker, Fukuchi, Wong, Zwi, Huhn, Dickman, & Foley, 1997). The bandhead of N_2^+ is at 391.4 nm, which can be generated by excimer pumped dye lasers, tripled YAG pumped dye lasers, doubled Ti-sapphire lasers, and doubled Alexandrite lasers. We received DURIP 95 funds for a Doubled Ti-sapphire laser which was had to be replaced by a Doubled Alexandrite laser, and which was delivered to HIPAS October 7, 1997. The new Alexandrite laser will be installed in the lidar build during the week of December 1-5, 1997. Tests at the factory (prior to shipment) showed that this laser emits 160 mJ pulses at 10 Hz at 391.4 nm with a line width of 0.0003 nm (one tenth the line width of a typical dye laser). The very narrow line emission is the result of "seeding" the laser cavity with a CW diode laser tuned to twice the 391 nm wavelength.

While originally waiting for the Ti-sapphire laser, the HIPAS lidar operated as a sodium lidar. However, operation with a large 2.7 m collector is much different (http://wood.phy.ulaval.ca/lmt/home.html, http://www.astro.ucb.ca/lmt.html). A new technique of laser alignment was developed which uses the fact that an LMT views absolutely vertically (Wuerker, 1997). In addition we learned to tune a dye laser to the optimum sodium wavelength with a commercial sodium vapor lamp (Wuerker, Wong, Simon, & Fukuchi, 1997).

The HIPAS lidar also has two photometers, one of which monitors sky light over 20° at 590 nm over a 10 nm bandwidth which includes the Na resonant lines as well as N_2^+ First Positive light. The other photometer similarly monitors light at 390 nm (also over a 10 nm bandwidth) which includes the bandhead of N_2^+. The sporadic sodium layers seen with the HIPAS lidar correspond to increases in the auroral light at both wavelengths, giving further credibility to the notion that sporadic layers are due to the electrojet and precipitating electrons and protons.

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WEB ADDRESS

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http://www.astro.ucb.ca/lmt.html

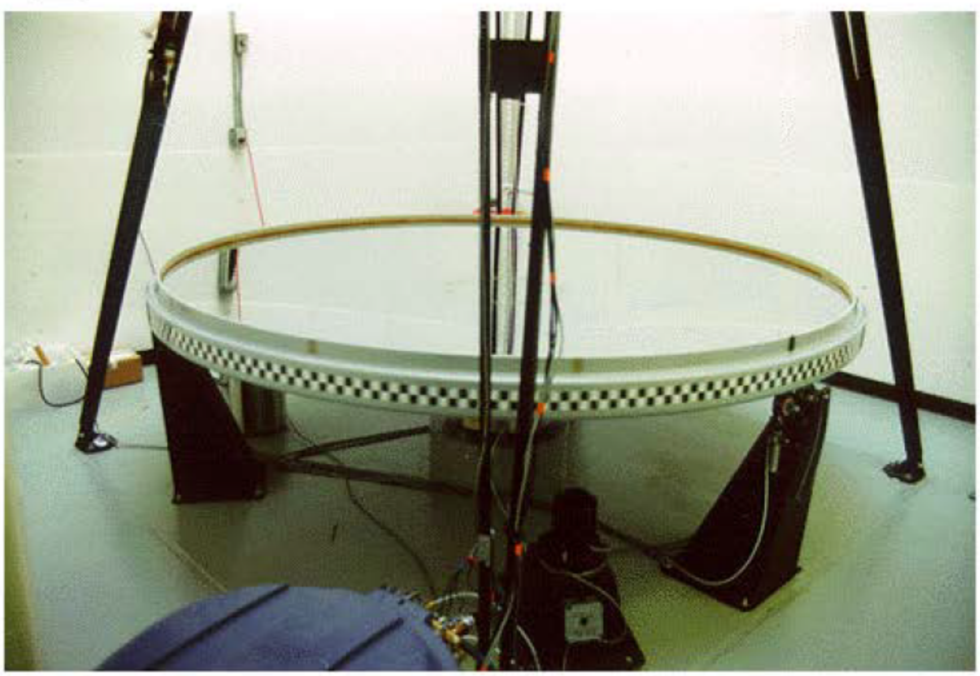

Figure 2: Photograph of the 2.7 meter diameter LMT lidar collector inside the HIPAS lidar building, under a glass sky light for winter -40°C operation.